

ECOLOGICAL STEWARDSHIP WORKSHOP

The National Park Service takes a step toward ecosystem management

By CRAIG L. SHAFER

LAST DECEMBER, 400 PARTICIPANTS from numerous federal agencies and nongovernmental organizations took part in a bold workshop entitled, "Toward a Scientific and Social Framework for Ecologically Based Stewardship of Federal Lands and Waters." The groundbreaking gathering, held on the outskirts of Tucson, Arizona, sought to develop a framework for implementing an ecosystem approach to managing federal lands and waters. Hosted by the University of Arizona, the U.S. Forest Service explained that the meeting aimed at shortening the 10-15 year development time historically needed to make routine use of scientific information in the management of federal lands. The product will be a compendium that outlines the options and alternatives and documents the scientific foundation for ecosystem management. According to the Forest Service, the framework is not intended to provide prescriptive solutions for individual sites or places, but will provide the foundation for the development of agency implementation plans and strategies.

PLANNING THE WORKSHOP

The workshop was a logical step in the progression toward ecologically based land and resource management. In 1994, the Congressional Research Service, the President's Commission on Sustainable Development, and the Interagency Ecosystem Management Task Force each added to the development of ecosystem management approaches on federal lands. This gathering built upon these earlier efforts.

This event was the brainchild of the U.S. Forest Service Chief Jack Ward Thomas, with planning and logistics carried out by Robert Szaro and William Sexton, also of the agency. Many agencies participated in planning sessions around the country to devise how the conference should be organized and what it should cover. This included the National Park

Service, which fully endorsed the event. The NPS involvement was coordinated by Natural Systems Management Office biologist John Dennis and Agate Fossil Beds Superintendent Ruthann Knudson; additionally, the National Park Service held periodic meetings at the conference to assess its involvement. Many sponsors also contributed to the success of the conference. They included the National Fish and Wildlife Foundation, Kendall Foundation, Pinchot Institute for Conservation, and Pew Charitable Trusts, to name a few.

PRODUCTS

The 10-day workshop centered on synthesizing existing scientific knowledge (including social sciences, economics, and legal considerations) and corresponding practical management experience on 30 key topics related to ecosystem stewardship. Each morning, selected *science team* authors delivered summaries of key points in the development of their papers. In the afternoon, *management team* authors focused on the successes, promising options, and failures related to the corresponding science topics. Participants contributed ideas in the afternoon management breakout sessions for the benefit of the management team authors. The result will be two parallel papers on each topic: a synthesis of existing scientific knowledge of the topic and a practical treatment of management experience in implementing these concepts on federal lands. The book containing these papers is being written and is expected to be published by a major university press.

EXPERIENCED PARTICIPATION

A diverse group including the U.S. Fish and Wildlife Service, U.S. Geological Survey, National Biological Service, Boise Cascade, Weyerhaeuser, Woods Hole Oceanographic Institution, Oak Ridge National Laboratories, and the Conservation Fund, and many others, participated in the workshop in hopes that they could make a difference in furthering ecosystem management. The science team

authors included many luminary figures from academia, government, conservation organizations, and industry. The management team authors came mostly from the U.S. Forest Service, Bureau of Land Management, and National Park Service. As the lists in tables 1 and 2 on page 14 attest, the National Park Service is participating in more than two-thirds of the 30 writing teams by providing both management and science team authors.

Agency heads also attended portions of the workshop. For example, the NPS Director and Deputy Director addressed participants, and ten top managers, including members of the NPS National Leadership Council, attended the end of the gathering. Near the close of the workshop, many agency heads, including those from the Bureau of Land Management, U.S. Geological Survey, National Biological Service, U.S. Forest Service, and National Park Service, signed a joint agency statement reflecting common ground. Deputy Director John Reynolds in a talk and subsequent memorandum to the National Leadership Council outlined immediate NPS follow-up to the agreement. More specific recommendations derived from the meeting will continue to be adopted.

CONCLUSION

Miraculously, this all happened within 8 months of the first major workshop planning session. Those involved in its planning thought it could never happen in such a short time—but somehow, it did! Why? Probably because it had to. The Forest Service said that this was the only timetable available to them. We also feared the possibility of political interference. Fortunately, no problems of this nature occurred.

The event helped demonstrate how natural and social science, history, and law are all components of ecosystem management. Such insights and integration will

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be provided on paper and although much work lies ahead to produce the final volume, the process is in motion. Managers will be able to use the detailed reference of over 60 scientific, management, and case study papers. However, the real test of the conference will come later as federal agencies and other land holders begin to implement some of the ideas discussed in Tucson.

GETTING INVOLVED

The process being used to exchange ideas and compile the written reports is provided on the Tucson workshop home page on the World Wide Web. The page may be accessed through the U.S. Forest Service home page or directly at <http://www.fs.fed.us/eco/workshop>. It includes a summary of the process, list of science and management topics, operating plan (including author team members), and both the science and management chapter outlines developed in Tucson. Many sci-

ence topic papers were already in draft at Tucson and are available for review and comment.

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TABLE 1. NPS MANAGEMENT TEAM AUTHORS

Author	Affiliation	Topic
William Anderson	National Capital Field Area Office (202-342-1443)	Cultural values/resource use
Jennifer Bjork	Cumberland Island National Seashore (912-882-4336)	Decision support
Steve Cinnamon	Great Plains SSO (402-221-3437)	Shifting human use
Brien Culhane	Everglades National Park (305-242-7700)	Regional cooperation
Muriel Crespi	Archeology and Ethnography Program, WASO (202-343-8156)	Cultural values/resource use
Joan Darnell	Alaska SSO (907-257-2648)	Legal perspectives
John Dennis	Natural Systems Management Office, WASO (202-208-5193)	Ecological functions; Scale phenomena
Mary Foley	New England SSO (e-mail—"mary_foley@nps.gov")	Land condition over time
Rick Harris	Curecanti National Recreation Area (970-641-2337)	Ecological classification
Ron Hiebert	Midwest Field Area Office (402-221-3461)	Population viability; Uncertainty & risk assessment
Anne Hitchcock	Museum Management Division, WASO (202-343-8138)	Data management, collection, and inventory
Dan Huff	Intermountain Field Area Office (303-969-2651)	Human role
A. Trinkle Jones	Western Archeological and Conservation Center (520-670-6501)	Heritage management
Donna Kostka	National Center for Recreation and Conservation, WASO (202-343-3669)	Social system functions
Ruthann Knudson	Agate Fossil Beds National Monument (308-668-2211)	Human role; Ecological economics
Jean McKendry	University of Idaho CPSU (208-885-7129)	Case study—Columbia River
Susan Mills	Alaska SSO (907-257-2573)	Stewardship, consensus processes
Earl Neller	Kalaupapa National Historical Park (808-567-6802)	Cultural values/resource use
Kathleen Picarelli	Chesapeake & Allegheny SSO (215-597-1628)	Regional cooperation
Richard Ring	Everglades National Park (305-242-7700)	Restoration & maintenance; Case study—South Florida
Dave Ruppert	Rocky Mountain SSO (303-969-2879)	Heritage management
Ray Sauvajot	Santa Monica Mountains National Recreation Area (818-597-1036)	Ecosystem and landscape diversity
Craig Shafer	Natural Systems Management Office, WASO (202-219-8934)	Ecosystem and landscape diversity
Page Spencer	Alaska SSO (907-257-2625)	Disturbance and temporal dynamics
Howie Thompson	Denver Service Center (303-969-2461)	Public expectations/shifting values
Gary Williams	Natural Resource Information Division, NRPC (970-225-3539)	Monitoring and evaluation

TABLE 2. NPS SCIENCE TEAM AUTHORS

Author	Affiliation	Topic
Don Calloway	Alaska SSO (907-257-2408)	Social/cultural classification
Steve Cinnamon	Great Plains SSO (402-221-3437)	Shifting human use
Muriel Crespi	Archeology and Ethnography Program, WASO (202-343-8156)	Cultural values/resource use
Dan Huff	Intermountain Field Area Office (303-969-2651)	Land condition over time
Rebecca Joseph	New England SSO (617-223-5056)	Social/cultural classification
Ruthann Knudson	Agate Fossil Beds National Monument (308-668-2211)	Human role
Gary Machlis	University of Idaho CPSU (208-885-7129)	Human ecosystems introductory book chapter; workshop summary

ECOSYSTEM

WHAT DOES IT MEAN?

By RON HIEBERT

CRAIG SHAFER DESCRIBED the format of the Tucson Ecosystem Workshop. As he stated, we do not know what the benefits or outcomes of this exercise will be. We hope written products will communicate to scientists what managers need and encourage managers to engage scientists in the decision making process. All National Park Service participants share the responsibility to incorporate what was learned into everyday park operations, planning, environmental education, and training. Following I give my impressions of what the Tucson workshop was all about, the lessons I extracted, and how I feel it applies to the way in which the National Park Service conducts business.

To me, the message of the workshop was change. Not so much change in what we do but change in how and why we do it. Ecosystem management certainly is not a new concept for the National Park Service. We have long professed that we manage for the whole system rather than for individual components. We say we recognize humans as an integral part of the systems we manage and that societal, cultural, and natural resources are interrelated. But, how often do we approach problems on this premise? Treating these parts separately often does not the whole make.

Ecosystem stewardship is about scale, both spatial and temporal. The National Park Service recognizes that parks are not islands and that they must be managed within the context of their regional landscape. It is less routine to strategically consider the role of a group of parks in a regional scale such as the Ozark Highlands or the Great Lakes Basin, the role of the park system in preserving national biodiversity or the role of parks in providing habitat for neo-tropical migratory birds in North America. On a temporal scale, the National Park Service has put

forth a concerted effort through such endeavors as the Vail Agenda to look at our changing role and how we must change to meet new challenges into the future. This kind of thinking needs to be scaled down to the cluster and individual park level more consistently and objectively.

The workshop also forced me to reexamine the meaning of stewardship, what it means to the federal land manager and specifically to us in the National Park Service who have been entrusted with stewardship of the nation's crown jewels for future generations. This is an awesome responsibility. We must, on a routine basis, find and apply the best information available in making management decisions. All of us must continue to hone our skills and keep abreast of new tools and technologies. Finally, we must involve the public in a meaningful way in park management. After all, they are who we serve.

The meeting also reemphasized the need for effective teamwork between managers and scientists and adoption of adaptive management principals. Managers need to engage scientists in the decision making process in ways that do not compromise their objectivity. Scientists need to be open to engaging in decision making to bring the best information to the table. This is a real challenge in our present structure with our former researchers now being transferred to the U.S. Geological Survey.

Further, we must recognize that "nature is dead." That is to say that the concept of systems uninfluenced by humans is now a myth. Therefore, it is up to us to define what we want the future condition of each park to be, develop a plan on how to get there, and apply evaluation criteria to see how we are doing. Simply saying our goal is to manage to protect "natural processes" will not do anymore.

Finally, management of parks will never again be as it was in the past. The public is no longer satisfied with the answer that

we are doing it this way because "that's our policy." If it is perceived that a proposed action may be controversial, we must make the effort to explain to park users the rationale of the policy and why we believe that action should be taken. We must also be armed with solid scientific data to support our decisions. For example, if one wishes to remove feral horses, which park users love, the park must effectively communicate the NPS policy concerning exotic species and have solid scientific data to document the impacts the feral horses are having on park resources. Then, we must be prepared to seek a mutually acceptable solution to the problem (see the cover story on FACA).

The Ecosystem Stewardship Workshop was about change. Not so much change in what we do but in how we do it. As stated by the Director of the U.S. Forest Service in his opening remarks at the conference, we must "change or die."

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STEWARDSHIP

THE ISSUE

To generalize, ORV user groups feel strongly that they should be able to drive the entire outer beach when the plovers are not present as they did before the seashore was established in 1961 (fig. 2). Conversely, the environmental groups feel that all ORVs should be banned from the beaches altogether. Many groups feel the answer is somewhere in the middle. The National Park Service, using the existing limited science on ORV use and resource impacts, and previous legal actions, feels that controlled, regulated use of ORVs on limited sections of the outer beach is not inappropriate, but that the majority of the outer beach should be vehicle free and that ORVs are not appropriate in sensitive resource areas (inner dunes, wetlands, marsh).

The objective of negotiated rule making is to *front-load* controversy by getting everyone involved in the decision from the beginning, and acknowledging (if not resolving) all issues and concerns. The process brings all interested organizations into the process and charges them with developing a common solution. This process is used by many federal agencies, most notably the Environmental Protection Agency (EPA), but this was the first time the National Park Service used it to make a rule that will be published in the Code of Federal Regulations (CFR). With recent criticism that federal land management agencies are facing for making isolated decisions, for example, we see this process as an important and growing tool.

THE PROCESS

Negotiated rule making is authorized under the Federal Advisory Commission Act, which provides for formal meetings to be open to the public. Meeting notices are published in the *Federal Record*. A public comment period at the end of each day is required as part of the process and those not in attendance can submit letters to be included in the record.

We began by identifying 23 groups (the maximum allowed is 25, although 6-7 is more common) that had a long-term interest and involvement in this issue. The organizations included state agencies, the six towns that the seashore is located within, ORV user groups, environmental



Figure 2. The negotiated rulemaking sessions resulted in a new regulation that closed a significant portion of the plover nesting beaches to off-road vehicle use. Elsewhere, ORVs are still restricted to a nonsensitive corridor, marked with stakes.

groups, federal agencies, and tourism and preservation groups. Each organization selects one person to represent them at the table. These representatives are the only participants in the formal discussions, and all are equal, including the NPS representative.

To avoid unbalanced votes, we managed the negotiated rule making as a consensus process giving each representative a veto. This approach helps get people out of their entrenched positions, pushes them toward the edge of what they can agree to, and gets them thinking creatively. A "threat" can also be used to create a further incentive to participate. In our case, we made the initial statement that the NPS would be developing a new regulation for off-road vehicles if negotiation failed. Either the regulation would be developed by the group, or it would be developed by the National Park Service with the ideas, information, and creativity gathered from the group.

The advantage of this process for the National Park Service, regardless of whether the group reached consensus on a regulation or not, was that every issue, idea, and concern was heard by all sides. Furthermore, the National Park Service was no longer the enemy, but was a participant just like the others. If we were to reach consensus, we made a commitment to publish that regulation in compliance documents and the *Federal Register* as our preferred alternative.

The Federal Advisory Commission Act not only facilitates the process, but also in our case created some challenges in getting it underway. For example, our rulemaking sessions began only after the process had been cleared, some 2-3 years after the idea was first proposed. Another delay was that all organization representatives (as opposed to the organizations party to the process) had to be appointed by the Secretary of the Interior. After the first meeting, one organization removed its original appointee and selected a new one who they felt better represented their views. This created a scramble, for the Washington staff had to get the new appointee approved within a very small window of opportunity. If the National Park Service is going to use negotiated rule making regularly, it would be very beneficial if the process and paperwork associated with it could be streamlined.

Professional negotiators, contracted through an EPA *indefinite quantities* contract, ran both the formal sessions and the advance meetings with each organization. The \$64,000 budget limited the formal sessions to just three, 2-day meetings. These were spaced a month apart to allow the representatives time to make sure that they were committing to things that their organizations could support and, very importantly, to allow time for behind-the-scenes interactions and negotiations. This is where much of the real work happens.

PREPARATION VITAL

The most difficult NPS decisions and thinking had to be done before the process began. We used the time between meetings to refine philosophies, determine our boundaries on issues, and consider new suggestions. It is important that every angle and approach be explored, even undesirable ones, so that the NPS position, at least in public, is unified. The NPS representative must be sure of these boundaries during the sometimes heated and demanding exchange that takes place in the negotiation room. Thus, preparation is key to the process.

Normally, the process would start from ground zero. However, because of the limited number of meetings, the professional facilitator asked us to be prepared to share a *straw dog* or unofficial position to initiate discussion. To develop this, we first assembled a wide variety of park staff. We analyzed every aspect of the existing regulation and brainstormed possible rewrites. This included considering alternatives that would not have been in our plan, if we had been developing it independently. Finally, we threw out all the options we could not live with.

While developing the position document, we needed to keep it to ourselves until we could formally present it in the first session. We did not want the plan to get out, have an attack developed opposing this plan, then find ourselves in the very human position of defending a plan that we had developed specifically to provoke discussion, rather than to identify our idea of the best solution. This was easier said than done. The very need to keep the document private prevented the entire staff from participating in these first discussions. This was a problem and we should have done a better job of getting the staff to understand the process and how they would be involved.

We also needed to collect and organize relevant data, files, decisions, and past research on the issue in advance of the meetings. This information had to be synthesized, analyzed, and distilled so the staff was aware of the history of the issue. The scientific reports and data helped identify what separated the acceptable options from the unacceptable. The representative had to be able to explain to the

committee the important points and ideas contained in these documents so that everyone could understand them.

Despite our preparation, we found that data often got in the way of the negotiation process. It was easy to get into a battle of "my expert" versus "your expert." Mountains of data and reports can overwhelm the group and the process, because some participants do not have access to expert information or may not understand the science behind the information; also, the claims of who has the better information, the correctness of the scientists, or the interpretation of the works can come into question. This creates the danger of raising tempers, because there is no way of resolving these issues among laypeople, and moves the discussion away from the central negotiation points. Our approach was to quickly disseminate scientific information, but only when necessary.

Between the second and third sets of meetings we put forward our first draft proposal, which was developed by a much larger circle of staff. This process was very much a parkwide, and in some respects a servicewide, effort. While just one person spoke for the National Park Service at the table, an enormous support team was behind the proposal. The team participated in numerous discussions between meetings, developed draft rules, reported the institutional knowledge on issues, and served as the reality check on the feasibility of different scenarios. Washington staff moved along the mountains of paperwork and requirements associated with FACA and reviewed draft proposals; the regional solicitor's office reviewed draft proposals and legal issues. Phone calls, e-mail messages, and discussions with other NPS areas around the country looked at their ORV issues and concerns.

SUMMARY

The National Park Service has been accustomed to making decisions, plans, and policy after consulting staff or other federal agencies; however, we must improve our ability to communicate with state and local agencies, critics, and supporters, and learn to listen to their concerns and issues. We need to involve and be involved with our local communities and agencies, and we need to work together on issues of mutual concern rather

than always seek public comment in traditional forums that keep us separate and above our critics. Although it promotes listening to our critics and involving them in the decision making process, negotiated rule making does not suggest that we abdicate our responsibility to protect resources or ignore the NPS mission. It simply requires that we not let resource preservation become a way of eliminating input or ignoring solutions developed by others. It requires us to be up front about our boundaries and to clarify a range of acceptable solutions. We found it to be a useful tool.

EPILOGUE

On the sixth and final day of negotiations, the ORV user groups and the environmental groups had a private 6-hour caucus. In the end, all 23 groups agreed to a new ORV regulation that closes a significant portion of the current ORV corridor, which is a prime plover nesting area from April 1 through July 20. The regulation also opens both a section of outer beach not currently available for ORV use (for night fishing only) and another small section of beach for general ORV use. Some small (two to three car) undeveloped parking lots will be established behind the primary dune for parking to accommodate fishing access. The new regulation also formalizes and recognizes the role that ORV users, serving as volunteers, play in education and resource monitoring and preservation.

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Linda Canzanelli is Deputy Superintendent and Michael Reynolds is Chief of Natural Resource Management. Both are at Cape Cod National Seashore, Wellfleet, Massachusetts. Each is accessible over NPS cc:Mail or by e-mail at "firstname_lastname@nps.gov". Additionally, the park phone number is (508) 349-3785; fax (508) 349-9052.

ASTER YUKONENSIS RANGE EXTENSION IN NORTHERN ALASKA

Vast wilderness surveys shed light on candidate threatened species status

Figure 1. Yellow centers and violet petals characterize the Yukon aster, a candidate threatened plant species in Alaska. Recent surveys in Gates of the Arctic National Park and Preserve revealed that the plant is more widespread than previously thought.

By DONNA L. DiFOLCO

IN JULY 1993, NPS RESOURCE managers discovered a small population of *Aster yukonensis* (fig. 1) on an island in the Middle Fork of the Koyukuk River in northern Alaska, within several miles of the only documented location of the plant in the United States. This discovery spurred interest in searching for more populations of the plant in neighboring Gates of the Arctic National Park and Preserve (fig. 2). The NPS staff at Gates of the Arctic have since found more populations of the Yukon aster along the Middle and North Forks of the Koyukuk River. Resource managers have also identified the plant in the Kobuk Sand Dunes in Kobuk Valley National Park.

The Yukon aster, a violet petaled, thin leafed aster of the Composite family, is currently listed as a candidate species, category 2, for the threatened and endangered species list. Knowledge of the plant's range and status is not yet fully understood, hence its classification as a category 2 species. Until recently, the Yukon aster had been known to occur only in southwestern Yukon, Canada, and at one location on the Koyukuk River, Alaska. The National Park Service is mandated by the Endangered Species Act to protect threat-

ened, endangered, or candidate species of plants and animals within the areas it manages; Gates of the Arctic National Park and Preserve has undertaken the task to locate and map *A. yukonensis* within its borders to meet this mandate.

In late July, 1994, a resource management crew surveyed approximately 58 km (36 mi) of the Middle Fork Koyukuk River, searching for the plant on every gravel bar (fig. 3) on the park side of the river (generally the north bank) and each island that was mostly on the park side. For the first day-and-a-half of the survey, we searched in vain. Finally, we came across the first population of *A. yukonensis* on a gravel bar of the park border.

Once we located the first specimens, we walked from one end of the gravel bar to the other in parallel transects. We counted each *A. yukonensis* seen on the gravel bar, from the thick organic mat of the forest edge to the sparsely vegetated strip nearest the river. The first specimens located were examined carefully by looking for the densely glandular phyllaries (the narrow, leaflike bracts at the base of the flower) to confirm identification. After this, we used macroscopic features, such as the long, narrow clasping leaves, to identify the species more quickly, and to distinguish it from other species (mainly *A. sibiricus*).

Some river bars harbored so many of the Yukon asters that it was impossible to count them all. In these high density areas, we dispersed across the gravel bar, each person searching a different section and counting asters. Then the individual counts were combined into a minimum estimate for the total site count.

The search turned out to be much more successful than expected, as we found Yukon asters growing on nearly every gravel bar in a 40-km stretch (25 mi) of the river bordering the park. Most sites had from 50 to over 400 plants on the gravel bars. Two sites supported at least 1,000 plants each. The plants seemed to prefer sites mainly where river silt had accumulated at the upper and lower ends of gravel bars and along sloughs.

Directly after the confluence with the North Fork Koyukuk, we found only a few Yukon asters. The sudden disappearance of the large populations was puzzling. A change in soil type could be one reason for the decline. Less silt accumulates just below the confluence than along other parts of the river because the sedimentation regime has been altered by North Fork river water. Farther down river from the confluence, population sizes increased again, with counts in the 50-150+ range. These populations were made up of scattered individuals, much like the popula-

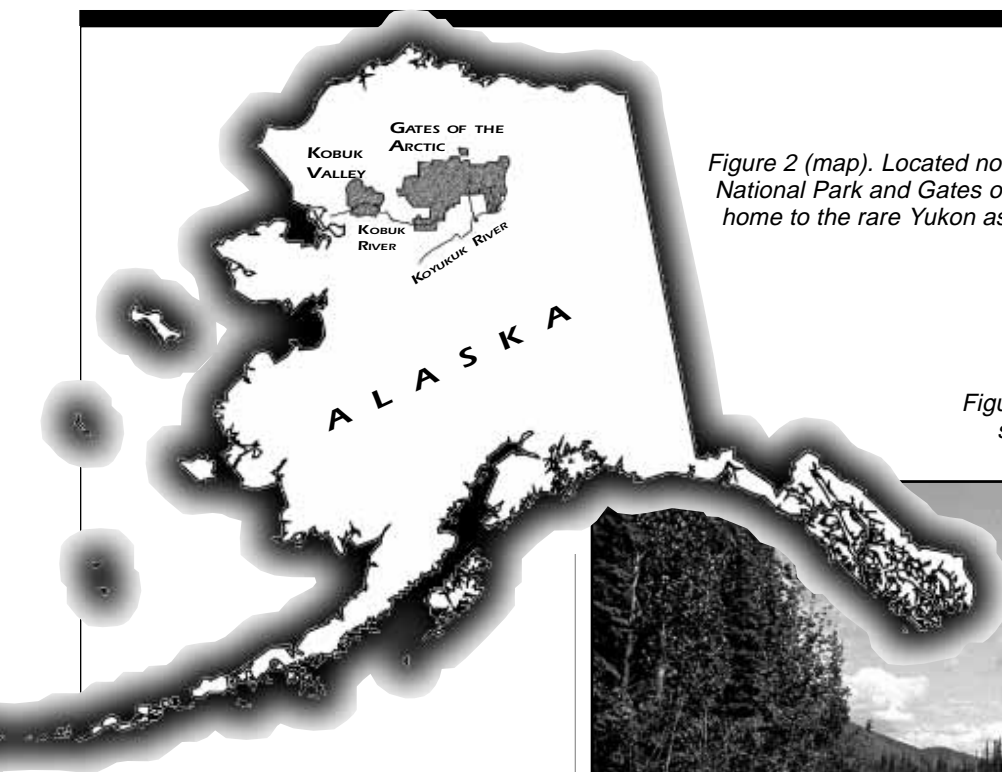


Figure 2 (map). Located north of the Arctic Circle in Alaska, Kobuk Valley National Park and Gates of the Arctic National Park and Preserve are home to the rare Yukon aster.

Figure 3 (photo). The aster grows along gravel bars, such as this one located on the Koyukuk River in Gates of the Arctic.

PHOTO BY DONNA L. DIFOLCO



tions where the first flowers were discovered. This type of distribution suggested that either the species was just getting established on the gravel bar or the soil type was not optimal.

About a month after the survey, a flood swept through the area, rivers swelling high above the 100-year flood water line. Concern that the flood wiped out the tenuous population of Yukon aster along the Middle Fork Koyukuk was relieved when biologists on a bird survey the following spring confirmed that some plants had survived the big flood.

In 1995, staff surveyed the North Fork Koyukuk River for the species, mapping more, albeit few and scattered, populations of the Yukon aster. Resource managers found 13 populations along the North Fork, totalling less than 300 individuals. We do not know whether more substantial populations existed before the 1994 flood or not. A second survey of the Middle Fork to reexamine gravel bars that supported sizeable populations of the aster might reveal whether the flood affected the flowers. If major floods have deleterious effects on populations of these rare plants, then this may explain why the plant is uncommon.

While *A. yukonensis* was being mapped on the Middle Fork Koyukuk River in 1994, it was also being discovered in the Great Kobuk Sand Dunes along the

Kobuk River in Kobuk Valley National Park (fig. 2). National Park Service personnel in Kobuk Valley found 23 populations of *A. yukonensis*, totalling about 1,500 individuals (Hunt, NPS, personal communication). The habitat types where the Yukon asters were found in the Kobuk Sand Dunes were similar to the silty-sand gravel bars they seemed to prefer along the Koyukuk River. The Kobuk Sand Dunes populations, found mainly in dune depressions, were not as robust in terms of density and numbers of individuals as some of the Middle Fork Koyukuk populations, but seemed to be better developed than the North Fork populations. Differences in soil type and the length of time since the last environmental extreme (e.g., flood or drought) may be reasons for variations in population densities.

The past two summers of field work have greatly expanded the known range of *A. yukonensis* in northern Alaska. The

plant is likely to occur in other areas as well. In summer 1995, Yukon asters were reportedly seen far into the mountains along Agiak Creek, a tributary of the Hunt Fork John River. As we gradually survey the vast areas of Gates of the Arctic National Park and Preserve and inventory its resources, we will begin to more clearly understand the distribution of rare plants such as *A. yukonensis*.

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LANDSLIDES & FOSSIL RESOURCES AT HAGERMAN FOSSIL BEDS:

A case study in landslide factor assessment

BY LAWRENCE P. GROWNEY

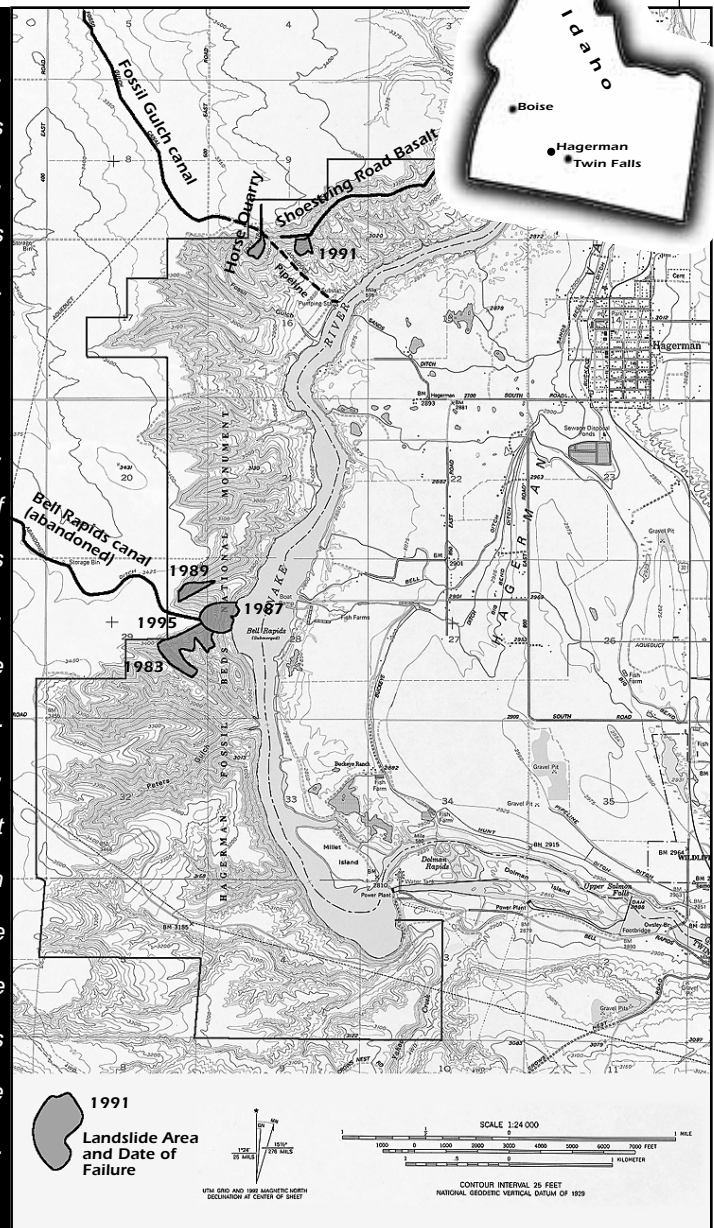
LOCATED 64 KM (40 MI) west of Twin Falls, Idaho (fig. 1), Hagerman Fossil Beds National Monument preserves abundant and diverse Pliocene-epoch fossils embedded in the banks of the Snake River. The quantity, quality, and variety of these 3-3.4 million year old fossils distinguish the monument internationally. Over 150 species, including mastodon, giant ground sloth, camel, bear, and the world famous Hagerman horse, have been preserved and identified in the Glenss Ferry Formation, which rises in cliffs to over 153 m (500 ft) above the Snake River.

Authorized in 1988, the park preserves the fossils and provides for paleontological research. However, landslides regularly disturb the fossils and endanger the safety of visiting researchers. Since 1983, landslides have decimated more than 2.7 million m³ (3.6 million yd³) of fossil-bearing material (Table 1 and fig. 2).

Concerned about this serious resource threat, park staff hypothesized that the landslides were the consequence of oversaturation of the Glenss Ferry Formation resulting from leaking, unlined, irrigation canals on the plain above the Snake River. Ironically, the park enabling legislation states that the preexisting water delivery system, which crosses the park, is "compatible and consistent with park purposes." However, for the monument to become a premier location for scientific study, we must be able to assure visiting researchers of a reasonably safe and productive research experience and preserve a coherent stratigraphic and depositional setting conducive to interpretation. To meet these goals, the park began a detailed landslide assessment process in 1993 to determine the factors resulting in the landslides and recommend solutions within the bounds of the legal mandates.

*Figure 1 (inset).
Hagermann Fossil Beds
National Monument,
Idaho, located 40 miles
west of Twin Falls.*

*Figure 2 (right).
Topographic map of
Hagerman Fossil Beds
National Monument.
Numbers identify the
year of major landslides.
The Horse Quarry site,
Shoestring Road Basalt
flow and Fossil Gulch
canal are visible at the
top center. The
abandoned Bell Rapids
canal location can be
seen in the left center.*



GEOLOGIC SETTING AND BACKGROUND

The fossil-rich Glenss Ferry Formation in the Hagerman area is composed of ashfall units and sediments deposited in lakes, rivers, and swamps during the Pliocene epoch 3-3.4 million years ago (Malde and Powers, 1972). A thin (<4.6 m or <15 ft) basalt flow crops out at the north end of the monument and is visible in the hillside northeast of the world fa-

mous Smithsonian Institution Horse Quarry (fig. 2). Known as the Shoestring Road Basalt, this flow is interbedded with the Glenss Ferry sediments about 122 m (400 ft) above the river.

The Desert Entry Act of the early 1960s, opened the plateau adjacent to what is now the national monument to farming (fig. 2). The Bell Rapids Irrigation District was created by the farmers to supply water for their needs. For more

than a decade, two pump stations moved nearly 51,000 acre-feet of water from the Snake River uphill 152 m (500 ft) through 48" diameter pipes to the plateau for distribution by canal (Anderson, 1995). Since a 1987 landslide that buried the Bell Rapids pump station (fig. 2), water to the irrigation project has been supplied by the Fossil Gulch pump facility. The pipeline from this pump station lies adjacent to the Horse Quarry and crosses over an extensive seepage zone.

From the Horse Quarry site, over 100 skulls and 30 complete skeletons have been recovered through past excavations. It is the most productive and scientifically significant locality for the species *Equus simplicidens* in the world. While the Horse Quarry site is open to visitors and researchers at the present time, this could change. Each year, nearly 500 acre-feet of seepage, and sporadic slope movement, occurs within a radius of 610 m (2,000 ft) of this site.

ASSESSING LANDSLIDE FACTORS

In 1994, we began a 3-year assessment effort to find a solution to the landslide threat. Using NPS NRPP (Natural Resource Preservation Program) funds, we first identified the fossil areas at greatest risk, and have begun to characterize the rocks, study the hydrology, and examine the soil strength of these areas. A key to accomplishing the work within the 3-year time frame has been to involve other public and private parties that have an interest in the Hagerman landslide issue (Table 2). Together we have shared our strengths and made quicker strides toward achieving our goals of minimizing landslides and their effects.

RESULTS

Studies examining the rock types, and their interlayering, support the Malde and Powers findings (1972) that the local Glens Ferry Formation is composed of layers (beds) of ashfall, lake, river, and swamp deposits, which dip gently to the south-southeast at about 3 degrees. It is important to note the distinction between dip of the beds and slope gradient. Dip of the beds is about 3 degrees while the slope gradients near landslide-prone areas are between 30 and 90 degrees. This is why seeps (and the landslides) occur on south- and east-facing slopes.

Nearly 75% of these beds are composed of very fine-grained particles, such as clay, which retard the downward flow of groundwater through the bed (Lee et al. 1995). When the water finds it easier to flow across the top of a bed, rather than through it, the bed is referred to as an *aquiclude*. The water held above an aquiclude forms a *perched aquifer*, or a body of groundwater occurring above the true water table. Young (1984) and Reidel (1992) have identified at least 4 perched aquifers within the monument.

Geophysical investigations of the perched aquifer system involved the use of geoelectric and seismic methods. Data gathered by a private firm under NPS contract demonstrated a tie between canal leakage and both the seeps near the Horse Quarry and the 1991 landslide

scarp. Furthermore, the contractor found that approximately 5,000 acre-feet of water, or about 10% of the total canal flow, leaks into the subsurface each year (Anderson 1995).

In the course of drilling six new monitoring wells, we learned that one of the perched aquifers occurs in the open fractures of the basalt flow (Young 1994; personal correspondence). Water supplied by this perched aquifer is the cause of the 1991 landslide (fig. 2), a small slump and pond, and the wide zone of seepage and instability occurring around the Horse Quarry site.

Groundwater monitoring has identified a cyclic pattern to the groundwater flow in the Horse Quarry area. Combined read-

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TABLE 1. MAJOR LANDSLIDES

Year	Scarp Location	Attitude	Height		Displacement Volume	
			m	(ft)	m ³	(yd ³)
1983	Bell Rapids	South	31	(100)	995,000	(1,300,000)
1987	Bell Rapids	East	62	(200)	918,000	(1,200,000)
1989	Bell Rapids	East	46	(150)	765,000	(1,000,000)
1991	Fossil Gulch	South	18	(60)	38,250	(50,000)
1993	Bell Rapids	East	no change		369	(482)
1994	Fossil Gulch	South	no change		84	(110)
1995	Bell Rapids	South	9-31	(30-100)	49,725	(65,000)
1995	Fossil Gulch	South	20	(65)	459	(600)
Total volume					2,766,387	(3,616,192)

TABLE 2. CONTRIBUTIONS TO THE LANDSLIDE ASSESSMENT EFFORT

Organization	Contribution	Staff Experts
Idaho State University	Stratigraphy, lithology, & soil analyses	Geologists
Boise State University	Seismic refraction	Geophysicists
USGS Water Resources Division	Monitoring, drilling, logging	Hydrologists
USGS Earthquake & Landslide Branch	Soil strength testing, mapping, monitoring	Geologists
USGS Photogrammetric Laboratory	Landslide volume quantification	GIS technicians
Private consulting firm	Geoelectric assessment	Geophysicists
Bell Rapids Irrigation District	Trenching, pipe laying	Equipment operator
Idaho Power Company	Monitoring, mapping, assessing hazards	Geologists, GIS support, ecologists



ings from the two monitored seep locations below the Horse Quarry vary from 416-1,022 liters (110-270 gallons) per minute; the lowest readings were recorded from May to July and the highest readings were from October to December. The seepage increase in the fall coincides with elevated groundwater levels in the study wells that tap the basalt aquifer (Young 1995; personal correspondence). Water is piped into the canal from May to September for use during the summer growing season. The rise in the groundwater table, and increase in seepage discharge volumes, consistently mirror canal usage with a lag response time of around 5 months (Young 1983, 1984, 1985; personal correspondence).

The key factors in understanding why the Glenns Ferry Formation has a tendency to slide are slope gradient and the strength of the soils relative to their moisture content. Samples taken from landslide scarps and landslide-prone areas, have been classified as high plasticity clays and silts (Chleborad and Schester 1995; personal communication). With these types of materials, as soil moisture increases, and with slope gradients of 30 degrees and more, the ability of the beds to maintain their cohesiveness is slowly overcome, culminating in a landslide. This process is responsible for all of the land-

slides within the monument and is occurring most notably within 610 m (2,000 ft) of the Horse Quarry.

SOLUTIONS

Dewatering provides immediate relief to slopes under stress where this stress is the result of increased saturation. A seismic refraction survey of the Shoestring Road Basalt (fig. 2) helped us understand the probable subsurface pathways for groundwater migration in areas underlain by the basalt, by delineating the margins and general structure of the flow. This information allowed us to identify six drilling sites that appeared to offer the best probability of encountering groundwater. Of the six wells drilled, three contain enough water to allow dewatering. Initial results suggest that an amount equivalent to 20% of the groundwater currently being discharged at the seeps in the Horse Quarry area could be intercepted at these wells. However, not all of the water intercepted at these three well sites is being discharged at seep locations in the vicinity of the Horse Quarry, so the overall effectiveness of dewatering activity on the Horse Quarry area is approximately 14% of total discharge. Based on the limited number of dewatering locations, this effort is inadequate to stop the landslides.

At best, it should reduce the frequency of failures and marginally improve the stability of affected areas.

Monitoring is essential in consistently and accurately tracking changes in slope behavior. Surface monitoring is critical for detecting movement in unstable areas for both visitor safety and research opportunity reasons. Subsurface monitoring is needed to track changes in groundwater levels, seepage discharge volumes, and soil moisture, all factors that contribute to landslide inception. While monitoring protocols implementation has begun, funding limitations have greatly slowed this process. By demonstrating the effectiveness of this monitoring program, we hope to encourage the financial participation of private parties in a joint, long-term monitoring effort.

The ultimate solution to the landslide problem involves keeping the groundwater away from the hillsides. Based on the geotechnical and hydrological data collected, a number of remedial methods are currently under consideration. Current plans call for the selection of a preferred alternative sometime later this year.

GRAVITY OF THE PROBLEM

Landslides destroy the stratigraphic and depositional relations needed to interpret prehistoric ecosystems. Furthermore, in-place material is buried beneath

Figure 3 (left). The scarp below the Bell Rapids Canal demonstrates the severity of the landslide problem at Hagermann with two slides showing clearly. The 1987 slide is just out of view in this image, obscured by the bluff.



Figure 4 (below). In the vicinity of the 1995 slide, author Larry Growney leads a crew to rescue a peccary fossil in danger of being compromised by additional slides. Water still seeps out of the hillside near the Bell Rapids pump station although the canal on the bluff has been abandoned for years.



the landslide debris making it inaccessible and lost to study. The hazards that landslides present to researchers and visitors may result in area closures, further impeding research and resource enjoyment. To understand the true impact of a landslide, consider the following figures approximated for the 1991 landslide:

Volume of failed material
38,228 m³ (50,000 yd³)
Area buried by landslide debris
4,180 m² (5,000 yd²)
Area of new scarp
1,338 m² (1,600 yd²)
New restricted zone above scarp
836 m² (1,000 yd²)

This example clearly shows that the total amount of land lost to paleontological exploration is much greater than just the volume of the landslide debris. Most park landslides occur at or very near the top of slopes. This means that the three-dimensional space (volume) lost to paleontological study can be much greater

than the numbers from the above example suggest. Moreover, the soil strength of the debris pile is much less than that of the original hillside prior to the landslide. As a result, the debris piles are likely to remain unstable, creating a long-term threat to field research and exploration on and below these features.

TIME AND PRESERVATION

We continue to inventory both long established and newly discovered fossil sites. Through the implementation of a monitoring protocol, which helps us set excavation and study priorities, many specimens have been recovered rather than lost to landslides. The combination of monitoring and fossil site inventory control gives us the ability to quickly identify threatened fossil sites, and respond before the scientific value of the resource is lost. However, even with these efforts, the landslides often beat us to the fossils. For example, a 3.2 million year old, still or-

ganic, log (see *Park Science* 14(1):7) was covered by a small landslide before it could be adequately sampled for study.

By taking steps to inventory fossil sites, use hydrologic, lithologic, and geotechnical assessment techniques, and implement monitoring protocols, we have built the foundation for improving a very bad situation, and we are well on our way to developing an ultimate solution. However, until the source of the groundwater recharge is stopped, major landslides, and resource degradation, will continue to play a role in the development of Hagerman Fossil Beds National Monument.

P S

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A social science tool for regional planning

Figure 1. Manassas National Battlefield Park, with its popular stone house, was just one of 13 Virginia parks recently analyzed for its economic contributions to the regional economy. Park operations and visitor expenditures play a substantial role in local economies and can help leverage park preservation issues.

ASSESSING REGIONAL ECONOMIC CONTRIBUTIONS FROM NATIONAL PARK SYSTEM UNITS:

By KEVIN L. GERICKE AND JAY SULLIVAN

Editor's note: "A Handbook for Assessing the Economic Contributions of National Park Service Units" (Sullivan et al. 1993b—as listed in the literature citations at the end of this article) contains further explanation of information presented in this article.

ACCORDING TO ITS MISSION, the National Park Service must make resource decisions seeking a balance between use and preservation. The tools of economics are useful in making these decisions, helping to justify investments, and allocating resources to national park system units. A simplified economic assessment tool known as the *money generation model* or MGM may be familiar to some readers as it has been circulated to parks to help managers and park neighbors gauge the economic impacts of the park on regional economies (see the companion article, "Why Assess The Economic Impacts of National Parks?, on page 26"). In a more detailed economic assessment of park contributions, three types of benefits occur: regional income and employment, resource values, and contributions to a community's sense

of well-being. This article presents major issues to consider when conducting an economic assessment of park contributions and examples from a case study of national park system units in Virginia (Shenandoah National Park, Colonial National Historical Park, Manassas National Battlefield Park, etc.—see fig. 1) (Sullivan et al. 1993a).

INCOME AND EMPLOYMENT VALUES

National Park Service operations often generate substantial income and employment in the surrounding region as a result of spending by visitors, the National Park Service itself, concessionaires, businesses, and other government agencies. The fundamental principle that guides the assessment of income and employment values is the *with and without* principle. That is, the analysis should identify only the income and employment effects that occur as a result of NPS operations in the region.

Two types of income and employment effects, direct and multiplier, must be considered. Direct income and employment effects are immediate economic activities generated by

NPS operations. For example, direct effects include money spent by visitors to the park or jobs created in local restaurants to serve visitors. Multiplier effects are additional rounds of economic activity set in motion by direct effects. For example, to provide a meal to a visitor, local restaurants require groceries, energy for lighting and cooking, and many other purchases in the region. This purchasing activity can occur in many rounds, until the initial money has "leaked" out of the region through purchase of goods and services beyond the region.

A multiplier describes total economic activity in an area (direct + multiplier effects) in terms of business output, income, or employment in a region. The multiplier "expands" direct effects to the rest of the regional economy. Individuals often use the phrase "money turnover" to describe how many times a dollar changes hands in an economy before it leaves through payments made outside the region. This definition is not the same as a multiplier, however. For example, a multiplier is not *seven* just because a dollar changes hands seven times in an economy. With each transaction,

the regional economy loses a portion of the original dollar through payment of taxes, purchases of goods outside the region, and in many other ways. This leakage may cause the original dollar to dissipate quite rapidly in a region. Multipliers greater than 3.0 are unusual, and are not likely to be credible with outside groups.

Depending on the detail of analysis, a variety of information is needed about park visitors: number of visits, average daily visitor spending, average length of stay in the area, visitor origin, and destinations. Information is also needed about NPS spending (payroll and operating expenses), other government spending, state and local taxes and in-lieu-of tax payments, associated business investment, and multipliers. An analyst can obtain much of this information from monthly public use reports, state tourism boards, travel organizations, visitor services projects (CPSU-based social science programs that serves NPS social science needs) reports, state tax commissions, and universities.

COMMONLY ASKED QUESTIONS

A common question about income and employment values is, "Do I include in my analysis those visitors who are residents of the region?" Income and employment effects often exclude spending by resident visitors. This approach is used because it is difficult to determine whether those visitors would have spent their money within the region if the park were not available (the with or without principle). Another question is, "Do I include the spending by visitors who stop at many attractions on their trip, with this unit being only one part of their trip?" It is only appropriate to consider the time and money spent in the vicinity of the park unit by these multiple-destination visitors. A third commonly asked question is, "Do I include concessionaire spending?" If the daily visitor spending estimates do not include purchases from con-

cessionaires, then concessionaire spending is considered; otherwise, concessionaire spending is not considered, to avoid double-counting.

A study of the economic contributions of NPS operations in Virginia estimated that total contribution to business output in the state from national park system units was \$474 million in 1993. Also, an estimated \$117 million in personal income and 9,000 jobs in Virginia resulted from NPS operations. These results indicate a substantial contribution to regional economies as a result of NPS operations (Sullivan et al. 1993a).

RESOURCE VALUES

A resource value is the amount individuals are willing to pay for the ability to enjoy the many goods and services that the National Park Service provides. While not as widely recognized as income and employment values, resource values are also significant contributions, because they may be more than what an indi-

The travel cost and contingent valuation methods are commonly used approaches for estimating resource values, and they require extensive visitor surveys. Economists have conducted hundreds of site-specific studies, resulting in a wide range of values for numerous activities (see Walsh et al. 1988 for a summary of studies). Other types of information are also indicative of the resource value individuals hold for units of the national park system, including membership in local conservation and historical societies, number of volunteer hours at a park, or the amount of public involvement in political and management decisions.

While it is difficult to conduct surveys for all parks in the national park system, an analyst can use previous studies to provide a first estimate of resource values. Information on visitation, travel costs, and visitor trip destinations are needed to calculate resource values. Park staff consider-

Estimated resource values for units administered by the National Park Service in Virginia range from \$2,000 to over \$51,000,000 per year.

vidual pays as an admission fee or travel expense, thereby contributing to overall national wealth.

Resource values arise from the use and preservation of an area. The value from using an area may come from a consumptive activity (e.g., fishing), a nonconsumptive activity (e.g., learning about the history of an area), or an indirect activity (e.g., reminiscing with family who have visited park system units). The value for preserving an area may come from visitors knowing that they will have an option to see the resource in the future if they choose, or that the resource is a bequest for future generations.

ing conducting an economic analysis may find local universities to be helpful in determining resource values.

Estimated resource values for units administered by the National Park Service in Virginia range from \$2,000 to over \$51,000,000 per year. Other information collected also provides an indication of the value related to preservation of natural areas in Virginia: over 1,200 people are members of the Committee to Preserve Assateague Island; the Sierra Club serves over 12,000 Virginia members; and 1,200 people belong to the Virginia Native Plant Society (Sullivan et al. 1993a). With information of all

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kinds about resource values, decision makers will be able to better understand why individuals desire certain management actions, provide for their needs, and maintain the integrity of the resource.

COMMUNITY VALUES

The National Park Service also contributes to the sense of well-being in communities by providing eco-

logical, cultural, and recreational services. In urban areas, respondents placed a higher importance on the open spaces the units provide than the local business effects (Sullivan et al. 1993a). Assessing NPS contributions to community values is as important as resource values or income and employment values in fully understanding the relationship between the National Park Service and people in the surrounding region.

PS

The National Park Service also contributes to the sense of well-being in communities by providing ecological, cultural, and recreational services.

logical, cultural, and recreational services. For example, open space provided by national park system units may contribute to the quality of life in an area. In Roanoke, Virginia, commuters often use the Blue Ridge Parkway, despite the fact that it is a slower route than interstate highways. However, the parkway offers individuals a chance to unwind after a busy day at work.

Several methods can be used to assess community values, including personal interviews, monitoring media coverage, and examining written visitor comments. We interviewed local governments, chambers of commerce, and NPS personnel in the Virginia study. Respondents indicated how important the services provided by the parks were to them. These services included education programs, regional economic activity, cultural and historic preservation, natural environments preservation, social opportunities, and various recreational activities. The results indicate a range of perceptions about the importance of parks. For example, respondents from rural areas near national park system units tended to place a high level of importance on the effects to

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WHY ASSESS THE

By RONALD R. SWITZER

FOR MANY YEARS TRADITIONAL park managers have done remarkably good jobs of protecting park resources and serving park visitors. Unfortunately, some stopped managing at park boundaries. That is to say, although they may have interacted with communities in their spheres of influence, too little time was dedicated to convincing those communities that the national park was an important neighbor, not just as a resource steward,

but as a driving force in their local and regional economies. As such, the parks heavily influenced the quality of life over large areas, and needed to be recognized and brought to the table as equal players in long-range opportunity planning and economic development discussions, discussions that set the tone for compatible development, and that have the potential to reduce unwanted threats to the parks.

Many park managers grew their careers under the notion that those who visited national parks were just *visitors*, people who passed briefly through the resources and left no impact on the resources or the economy. In truth, the National Park Service has been in the tourism business since before it was officially designated in 1916, and what we do has dramatically affected local development and economics adjacent to all parks. Seldom have we taken stock of our contributions, and less frequently have we let our neighboring communities know the extent of those contributions.

While serving as tourism coordinator for the 13 national parks in Texas in a collateral duty capacity to the

ECONOMIC IMPACTS OF NATIONAL PARKS?

position of Superintendent of Big Thicket National Preserve, the Texas superintendents began helping me assemble economic impact information on an annual basis. This information was made known to the local communities, and synthesized as educational information for the Texas Departments of Commerce and Transportation. The significance of the economic contributions of the parks became a catalyst for the formation of a federal-state tourism coordinating committee involving more than a dozen agencies. Eventually, this group split into the Federal Tourism Council and the State Tourism Council, both of whom signed a memorandum of agreement to participate as partners in the Texas strategic tourism plan and to work toward accomplishing mutual goals and objectives.

At the local level, Big Thicket National Preserve assumed the leadership of a potent group of federal and state agencies, local chambers of commerce, tourism bureaus, and businesses in the private sector, to further resource-sensitive tourism and outdoor recreation, economic development, and environmental education. This same approach is currently being pursued in Kentucky, and while it is too early to assess whether it will succeed, indications are positive. The current Kentucky tourism master plan calls for the formation of a federal tourism council, and one is in the making.

Assessments of economic impact applied in positive ways can draw the national parks closer to the communities they serve. While past and current assessments in Texas and Kentucky have been based largely on the NPS *Money Generation Model* (contact Ken Hornback of the Washington Office Socioeconomic Studies Division at (303) 969-6977), the results tend to be very conservative

Figure 1. Mammoth Cave National Park, Kentucky, is the single largest resource attraction in the state.

Assessments of economic impact applied in positive ways can draw the national parks closer to the communities they serve.



because they are based on low multipliers, and do not take full account of all economic factors. State generated models (and the one described in the preceding feature article) generally yield much higher impact figures, higher by 25-40%. Whatever model is used, the results are extremely important as barometers of the economic worth of the national parks locally, regionally, and even statewide. Because Mammoth Cave National Park is the single largest resource attraction in Kentucky (fig. 1), the impacts it generates are noticed at the highest levels of state government. When the impacts of the four Kentucky national park units are considered, our worth to the economic well-being of the commonwealth is fully appreciated.

We have made good use of the Money Generation Model, but you should be aware of some of its shortcomings. As already mentioned, the multipliers are applied very conservatively, probably under-estimating economic benefits by a considerable factor. Furthermore, the full impacts of concessioners are not taken into account because of the danger of counting visitor impacts twice in the same model. The calculations do not recognize that concessions operations contribute more than the capital improvement expenditures used in

the formula for "other" expenditures when concessions operations *do* contribute more. Similarly, it fails to fully assess the impacts of employee expenditures for housing, health care, education, recreation, and living expenses locally. In addition, most models do not take into consideration the contributions of the National Park Service in funding and grants for urban park and recreation projects executed under statewide plans.

If the Money Generation Model does not fulfill your needs, I encourage you to work with your nearest cooperative park study unit, university department of park or outdoor recreation planning, or state department of travel development to develop one that measures critical economic impact. This helps assure that the information becomes a visible and appreciated part of growing partnerships with your local constituencies. Trust me, this works.

PS

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PSEUDOREPLICATION ISSUES VERSUS HYPOTHESIS TESTING AND FIELD STUDY DESIGNS

Alternative study designs and statistical analyses help prevent data misinterpretation

By ROY IRWIN AND LYNETTE STEVENS

Editor's note: *Pseudoreplication issues are complex, and space constraints allow only an introduction here. A more detailed recap and a related summary of impacts considered de minimis¹ (small enough to be trivial) is available through e-mail from Roy Irwin, "roy_irwin@nps.gov".*

PSEUDOREPLICATION HAS become a popular buzzword that has attracted considerable interest, controversy, and confusion. The debates over pseudoreplication began with Hurlbert's introduction and definition of the term pseudoreplication as:

The use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent (Hurlbert 1984).

Since 1984, many papers have attempted to refute, better explain, and expand on the issue of pseudoreplication. Pseudoreplication occurs when classical hypothesis-testing treatments are not technically replicated or statistically independent. Pseudoreplication often involves (but is not limited to) situations where investigators extrapolate site-specific statistical inferences beyond the situation that was studied. Pseudoreplication does not describe just a particular type of experimen-

tal design, but rather a particular category of misinterpretations or incorrect analyses.

Although many NPS studies involve routine inventory and monitoring rather than experiments to document effects of various stresses, staff doing inventory and monitoring studies should be aware of pseudoreplication issues. In many cases, others will eventually compare past and present data in an attempt to get insight as to whether or not a trend is developing or whether or not some impact (a treatment) is causing resource deterioration. Therefore, inventory and monitoring studies should be designed to maximize their utility for future trend or injury analyses.

Pseudoreplication does not describe just a particular type of experimental design, but rather a particular category of misinterpretations or incorrect analyses

EXAMPLE

A common example of pseudoreplication occurs when repeated observations of a subject are substituted for replicated applications of a treatment on different subjects. In this situation, the sample design calls for taking measurements over time, but uses only one control and one treated site (subject); data are not spatially replicated. For example, consider a common before-and-after study to determine effects on aquatic biota from some point source effluent entering a stream (e.g., a power plant on a river).

The study design consists of two sample points: one above the input and one below. Although several samples may be collected above, and several below, these are not true "replicates" for purposes of hypothesis testing coupled with inductive (from specific case to general case) inference, since there is only one treatment (the power plant effluent) and one experimental unit (the specific river). Due to lack of true replication, inductive statistics should not be applied. In other words, you cannot use the results of this study to generalize about any other power plants or other stream systems, or even to conclude that the power plant caused the difference seen in this one situation.

A key point to keep in mind is that Hurlbert's original definition concerned pseudoreplication with respect to testing effects of treatments. By common (mis)usage, some have also used the term pseudoreplication more broadly to include such things as no replication or inappropriate replication, even in the absence of an effort to examine treatment effects (cause and effects) through the use of inductive statistical inferences. Examples would include the following: (1) taking three sediment samples from one area, thoroughly mixing the three in a pan, putting portions of the mixed sample in three separate jars, and then calling the

three jars three "replicate" samples; or (2) taking three samples so close together in time or space that they are really more like one sample than three samples.

In routine monitoring, these examples of questionable replication, in the absence of treatment effects testing, may be considered unwise or inappropriate, but would not be considered pseudoreplication under Hurlbert's original definition. Although often done, criticizing a data set as "pseudoreplicated" is usually inappropriate unless statistical inferences are made for cause and effect.

¹ The phrase *de minimis* is an abbreviated form of the Latin phrase "de minimis non curat lex," which translates to "the law cares not for small matters;" in risk assessment, *de minimis* impacts are those that are so small (and not related to special resources such as endangered species) that one can disregard them.

PSEUDOREPLICATION ISSUES IN ECOLOGY

Due in part to large amounts of natural variance, lack of baseline ecological data, and lack of adequate funds for complete replication of studies (or treatments), occurrence of pseudoreplication is especially

cedures. **Illustration**—If you measured the length of 97 plants in a quadrat, report one number, (the average or median, for example). Avoid the temptation to say $N=97$; instead, say $N=1$.

Red flag #4—Measurements on the effects of a single point source on a river, up- and downstream. Limiting the statistical inference to that unique location above and below is not pseudoreplication.

Note: It is safest not to expand your inferences beyond that one site and situation and not to pretend that your significant levels or various statistical inferences prove the cause of any differences noted.

Field situations are often uncontrolled, unreplicated, and typified by so many confounding variables that cause and effect is difficult to establish.

STATISTICS APPLIED TO THE SCIENTIFIC METHOD AND RISK ASSESSMENT

high in ecological research. Pseudoreplication is not inevitable if an experiment lacks treatment replications, but occurs only if the researcher misleads the reader by applying inappropriate statistical analyses or misstating the strength of the evidence obtained (Hargrove and Pickering 1992).

However, lack of true replication should not be portrayed as an evil to be avoided in all situations. Often pseudoreplicated (or unreplicated) studies cannot be avoided in disciplines such as medicine, regional ecology, observational field ecology, and astronomy, but the state of "scientific" knowledge or site-specific or issue-specific understanding of issues still slowly progresses to new heights, mostly through weight-of-evidence approaches. Just as astronomers cannot directly manipulate stars, and therefore are prone to pseudoreplication, regional ecology research is difficult or often impossible without pseudoreplication (Hargrove and Pickering 1992). While population studies of animals with large home ranges may not be appropriate for experimentation, sample surveys and demographic studies may still be used to assess population effects (Skalski and Robson 1992).

The following are red flags for potential pseudoreplication problems (Meyer et al 1994):

Red flag #1—Use of more than one data point from given random or systematic plots or locations. **Solution**—Use one datum per sampling unit in statistical pro-

Notes: Many contaminants and biology effects data sets are not normally distributed, so it is often preferable to use nonparametric methods, to dispense with means and variances altogether, and to utilize alternative descriptive measures of central value and variability for skewed data, such as the median and interquartile ranges—IQR (Heisel 1990). In epidemiology work, a common practice is to compare only three groups: those with clearly high doses, those with clearly low (or no) doses, and an intermediate group. Even random selection of study sites from assessment and reference areas is "subsampling" or pseudoreplication if statistical conclusions are extrapolated beyond the assessment and reference areas (Meyer et al 1994).

Red flag #2—Use of the same plots or locations over time (OK for determining what happens to that one plot but not for larger universes).

Red flag #3—Multiple observations on same animal (OK for determining what happens to that one animal but not for determining what happens to populations).

The ideal way to build scientific knowledge is to use the scientific method in true experiments. A typically recommended scenario would be to combine genuine replication with random assignment of treatments to experimental units or probabilistic sampling from a study area (personal communication, Lyman L. McDonald, West Inc., 1995). However, while genuine replication is a powerful tool that should be used when possible, the scale of ecological research should not be dictated by statistical constraints (Hargrove and Pickering 1992).

In the absence of truly random samples, convincing evidence of an effect requires the effect to be demonstrated consistently at different times in different places (Meyer et al 1994). Consistent effects of incidents comprise a non-statistical type of inference. Such inferences are deductive (general case to specific case) or nonstatistical (Meyer et al. 1994). Although difficulty in replicating large-scale field manipulations makes quantifying

The problem is often triggered when the investigator uses a classical null hypothesis testing analysis and overstates conclusions related to the causes of the differences

Continued on page 30

cause and effect relationships difficult, this loss of statistical inference to pseudoreplication may be offset by carefully developing ecological inferences (Hargrove and Pickering 1992).

the statistical conclusions of a manipulative experiment extend to the protocol by which the study was conducted while the statistical conclusions of an observational study are limited to the specific assess-

and *Ecological Risk Assessment*. A synopsis of the information is presented here with permission of Glenn Suter):

"In ecological epidemiology there is no random assignment of populations or communities to treatments and treatments are almost never replicated so we cannot use statistics to test the hypothesis that populations or communities treated with a pollutant are different than those that are not.

There is no truly random assignment of treatments. The investigator cannot randomly assign some reaches to be treated with an effluent and others not to be treated.

In other words, while hypothesis testing requires random assignment of treatments, the investigator has typically had no role in where the effluent pipe was placed.

In field studies there is often only one treatment (an effluent, for example) rather than replicated treatments. Multiple biological samples (for example, benthic macroinvertebrates) are often taken above and below the effluent. However, the downstream samples are taken from one community affected by a single effluent and the samples are pseudoreplicates from that one treatment. In other words, samples from above and below a discharge pipe are not true replicates, they are pseudoreplicates since there is only one treatment.

The question often arises: can't we use hypothesis testing if we do it right? There have been heroic efforts to do so (for example, the Stewart-Oaten, BACI design which nevertheless does not totally solve the problem).

Since there is an inherent bias in favor of the null hypothesis, hypothesis testing places disproportionate burdens on environmental protection. Those who would protect the environment are required to prove with 95% confidence that effects are occurring. This bias is defensible in pure science but indefensible in risk assessment; it rewards polluters who perform poor studies with few replicates and high variances due to sloppy techniques. Hypothesis testing provides less protection for organisms less abundant or more difficult to sample.

Pseudoreplication can be avoided by applying truly replicated treatments or by restricting the generality and comprehensiveness of one's conclusions.

Ecological (deductive, weight-of-evidence) but not statistical (inductive) inferences can be made even when treatments are not replicated (personal communication, Lyman L. McDonald, West Inc., 1995). For example, normic statements (i.e., statements of what usually or normally happens that are generated by the collective outcomes of repeated experiments) can be the result of pseudorelicated experiments. Although these statements are not universal, probability based, or predictive, they represent generalizations with exceptions. Even so, the information content of normic statements is high in terms of explanatory power (Hargrove and Pickering 1992).

Some of the problems related to pseudoreplication in field studies arise because the investigator is conducting an observational study rather than a manipulative experiment. The problem is often triggered when the investigator then uses a classical null hypothesis² testing analysis and overstates conclusions related to the causes of the differences. This has become common partly because most standard textbooks dealing with statistics and biological study design do not adequately distinguish between statistical conclusions drawn from manipulative experiments and statistical conclusions drawn from observational studies (Meyer et al 1994). The arithmetic analysis is often the same for both types of design, but

ment area, reference area(s), baseline conditions, and assessment period in the study (Meyer et al 1994).

HYPOTHESIS TESTING AND PSEUDOREPLICATION

Pseudoreplication problems are often partly the result of inappropriately trying to force non-replicated data into classical null hypothesis testing molds. Descriptive statistics, predictive methods, or various other observational data analysis methods are often more appropriate than classical null hypothesis testing schemes for environmental observational studies, injury assessments, many before-and-after (BACI) applications, upstream-downstream studies, and ecological risk assessments.

At least some hypothesis testing assumptions are typically violated in field studies. A thorough discussion of the pitfalls of using hypothesis testing in field study applications would require a separate article, but the following notes from Suter regarding hypothesis testing versus risk assessment and field studies are helpful in understanding pseudoreplication issues. The following points were presented briefly in Suter's *Ecological Risk Assessment* Text book (Suter 1993) and expanded in a platform session paper presented at the National SETAC meeting in Denver, November 3, 1994: entitled "The abuse of hypothesis testing statistics in ecological risk assessment." A paper of the same title and basic content was in press as of January 1996, in *Human*

² The null hypothesis is the hypothesis that an observed difference (as between the means of two samples) is due to chance alone and not due to a systematic cause.

Polluters love hypothesis testing since it can be done with poor data.... They can then fail to reject the null hypothesis and the environment is not cleaned up.... Our real problem is often defining real significance.... Often we should use descriptive rather than experimental statistics."

SOME SOLUTIONS

Two study sites in a single area, for example, just up- and downstream of a discharge, can properly be sampled and compared using descriptive statistics relating to magnitudes, variances, and trends. Some would say they could also be compared using a classical null hypothesis testing scheme, while others would say a null hypothesis testing scheme should not be used. Both would agree that no matter which statistical methods are used, if a difference is shown, the investigator only knows that they are "different," has not proved why they are different, and should be careful not to generalize the results to other sites, times, or conditions that were not studied. Although field researchers have sometimes determined that the samples are "different" using hypothesis testing, conclusions as to why they are different often cannot be drawn (Suter 1993).

Some experts say the results (that the samples are different) of hypothesis testing at one site could be used as one of several clues making up a weight-of-evidence argument related to effects at that one site. Other experts would argue that it is better to use descriptive statistics to suggest that the samples are "different" and thereby avoid any hint of an incorrect conclusion that cause and effect has been "proved" at any given significance level.

A key point to keep in mind is the importance of properly limiting inductive inferences or conclusions. Pseudoreplication can be avoided by applying truly replicated treatments or by restricting the generality of one's conclusions (i.e., not overstating results) (Dixon and Garrett 1994). Some would argue that restricting the generality of one's conclusions might sometimes involve stating that you do not know why the samples are different.

Instead of hypothesis testing, using descriptive statistics and a weight-of-evidence approach to link potential relationships is often better (Suter 1993). Field situations are often uncontrolled, unreplicated, and typified by so many confounding variables that cause and effect is difficult to establish. The weight-of-evidence approach (which often includes statistical data from both field and lab sources) is often safer in ecological, risk-injury assessment, and contaminants field work (Suter 1993, Chapman 1995).

It is sometimes acceptable to set up the analysis in terms of tests of bioequivalence in the following manner: Assume the treatments will result in a difference in bioequivalence, including variation up to de minimis amounts of acceptable natural variation. The investigator determines the level at which there can be a change without exceeding bioequivalence thresholds (for example, a percentage change in an endpoint such as biomass or number of taxa). If the effect does not exceed a certain percentage previously chosen by the investigator as a trivial or de minimis change, the change has not exceeded a bioequivalence threshold. Such an approach requires the investigator to deal with issues of natural variation and confidence.

CONCLUSIONS

Understanding the intricacies of pseudoreplication and hypothesis testing versus field study design issues is not an easy task. The importance of proper determinations of the interrelationship between study objectives, study designs, data analyses, and statistical inferences in field investigations cannot be stressed enough (Skalski and Robson 1992). Those lacking expertise in statistics, may find it wise to first consult a statistician familiar with pseudoreplication and the study design issues discussed herein (not just any handy statistician or book). It is also wise to develop a written (and defensible) statistical design plan prior to beginning the study.

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Meetings of Interest

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JULY 7-10

To be held in Keystone, Colorado, the 51st Annual Conference of the Soil and Water Conservation Society will address conservation and ecosystem science, ecological decision making and management, and sustaining ecosystems. For more information, call 1-800-THE-SOIL.

AUGUST 11-15

The Ecological Society of America will hold its annual conference in Providence, Rhode Island. The National Park Service will host a panel discussion on its natural process wildlife management policy. For more information, contact the society at 2010 Massachusetts Avenue, NW, Suite 400, Washington, DC 20036; e-mail: "brian@esa.org".

AUGUST 19-22

The 15th annual North American Resource Modeling Conference, Evolutionary Consequences of Resource Management, will take place in Lutsen, Minnesota. Sessions will address the potential for evolutionary biotic and ecosystem change as a result of global human impacts. The conference will bridge the gap between theoretical ecology, evolutionary ecology, and natural resource management (including the idea of sustainable yield) in examining issues that involve natural resource modeling. Contact Julie Karels of the Department of Fisheries and Wildlife, 200 Hodson Hall, University of Minnesota, St. Paul, MN 55108.

SEPTEMBER 9-20

Front Royal, Virginia, will be the venue for the technical conference, Biodiversity Monitoring at Permanent Plots. Contact the Smithsonian Institution/MAB Program, 1100 Jefferson Drive, SW, Suite 3123, Washington, DC 20560; fax (202) 786-2557, for more information.

SEPTEMBER 14-19

Florence, Italy, will play host to the 17th International Meeting for specialists in air pollution effects on forest ecosystems. Entitled, Stress Factors and Air Pollution, the gathering will focus on recently discovered effects of air pollutants on forest ecosystems, with special reference to the interactions between environmental stress factors. Sessions include: interactions between air pollutants and abiotic and biotic stress factors; impacts on wildlife and ecology; air pollution and global change; and biodiversity conservation. For more information, contact Dr. E. Paoletti; C.S. Patologia Specie Legnose Montane; CNR, Piazzale delle Cascine 28; I-50144 Firenze; Italy; phone 39-55-368918; e-mail: "raddi@cspslm.fi.cnr.it".

OCTOBER 19-21

The American Society of Landscape Architects will hold its annual meeting in Los Angeles. This exposition will focus on compelling evidence of landscape architecture work in planning, design, and technology that contributes to societal well-being. Contact Cheryl Wagner (Fax: 202-686-1001; e-mail: "cwagner@asla.org") for more information.

OCTOBER 25

Bandelier National Monument, Santa Fe National Forest, and the Los Alamos National Laboratory are co-hosting a no-fee Symposium of Biological Research in the Jemez Mountains, New Mexico, in Santa Fe. Contact Stephen Fettig ("stephen_fettig@nps.gov"; 505-672-3861, ext. 546), NPS Wildlife Biologist at Bandelier, by July 1 if you are interested in making a presentation; abstracts are due September 15.

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